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Sixth Semester B.E. Degree Examination, July/August 2021
Heat and Mass Transfer

Time: 3 hrs.

Max. Marks:100

Note: 1. Answer any FIVE full questions.**2. Use Heat and Mass transfer Data Hand Book is permitted.****3. Assume missing data if any.**

1.
 - a. Write basic laws governing each mode of heat transfer along with mathematical expressions. **(06 Marks)**
 - b. Write boundary conditions of first, second and third kinds. **(06 Marks)**
 - c. Consider a slab of thickness L . A fluid at a temperature 130°C with a heat transfer coefficient $250\text{ W/m}^2\text{C}$ flows over the surface at $x = 0$, and another fluid at a temperature 30°C , with a heat transfer coefficient $500\text{ W/m}^2\text{C}$ flows over the surface at $x = L$ of the plate. Assuming K for the slab $20\text{ W/m}^2\text{C}$, calculate the heat flow rate per m^2 of slab if the slab thickness is 4 cm . Determine the slab thickness if the heat flow rate is to be reduced to 50% . **(08 Marks)**

2.
 - a. Derive an expression for the temperature distribution $T(x)$ and for heat flow through an area A of the slab of thickness L . Boundary conditions are at $x = 0$, $T = T_1$ and at $x = L$, $T = T_2$. There is no energy generation in the solid and thermal conductivity is constant. **(10 Marks)**
 - b. Explain (i) Critical thickness of insulation (ii) fin efficiency. **(04 Marks)**
 - c. A steel rod of diameter 2 cm , length 20 cm and thermal conductivity $K = 50\text{ W/m}^2\text{C}$ is exposed to ambient air at 20°C with a heat transfer coefficient $64\text{ W/m}^2\text{C}$. If one end of the rod is at a temperature 115°C , calculate the heat loss from the rod. Assume long fin. **(06 Marks)**

3.
 - a. Explain the significance of,
 - (i) Biot number (ii) Fourier number. (iii) Heisler charts. **(06 Marks)**
 - b. Explain the criteria for neglecting internal temperature gradients. **(04 Marks)**
 - c. The temperature of a gas stream is measured with a thermocouple. Junction may be approximated as a sphere of diameter $D = 2\text{ mm}$, with $K = 30\text{ W/m}^2\text{C}$, $\rho = 8600\text{ kg/m}^3$, $C_p = 400\text{ J/kg}^{\circ}\text{C}$. The heat transfer coefficient is $h = 280\text{ W/m}^2\text{C}$. How long will it take for the thermocouple to record 98 percent of the applied temperature difference? **(10 Marks)**

4.
 - a. Sketch and explain in brief each of the following:
 - (i) Velocity boundary layer for flow along a flat plate.
 - (ii) Thermal boundary layer for flow of a hot fluid over a cold wall.
 - (iii) Hydrodynamic entry region and hydrodynamically developed region. **(12 Marks)**
 - b. A square plate 0.4 by 0.4 m maintained at a uniform temperature of $T_w = 400\text{ K}$ is suspended vertically in quiescent atmospheric air at $T_{\infty} = 300\text{ K}$.
 - (i) Determine the boundary layer thickness $\delta(x)$ at the trailing edge of the plate (at $x = 0.4\text{ m}$)
 - (ii) Calculate the average heat transfer coefficient h over the entire length of the plate by using the relations given below :

Properties of air at 350 K

$$\gamma = 20.75 \times 10^{-6}\text{ m}^2/\text{s}, P_r = 0.697, K = 0.03\text{ W/m}^2\text{C}$$

$$\delta(x)|_{x=L} = 3.93 P_r^{-\frac{1}{2}} (0.952 + P_r)^{\frac{1}{4}} G_r^{-\frac{1}{4}} L, \text{NU}_m = 0.518 (G_r L P_r)^{\frac{1}{4}}.$$

(08 Marks)



- 5 a. What is the physical significance of,
(i) Reynolds number. (ii) Prandtl number. (04 Marks)
- b. The convection heat transfer coefficients for flow of a fluid through a tube have been experimentally determined. Using dimensional analysis obtain the relationship
 $Nu = f(Re \cdot Pr)$
The following physical quantities may be assumed to influence convection :
(i) Tube diameter, D (ii) Thermal conductivity, K
(ii) Velocity, u (iv) Density ρ .
(v) Viscosity, μ (vi) Specific heat, C_p and
(vii) Heat transfer coefficient, h (08 Marks)
- c. Water flows with a mean velocity of $U_m = 2$ m/s inside a circular pipe of inside diameter $D = 5$ cm. Assume the pipe is smooth and maintained at uniform temperature $T_w = 100^\circ\text{C}$ by condensing steam on its outer surface. At a location where the fluid is hydrodynamically and thermally developed, the bulk mean temperature of water is 60°C . Calculate the heat transfer coefficient h using (i) Dittus and Boelter equation (ii) Sieder-Tate equation.
Take properties at 60°C (mean T)
 $K = 0.651$ W/m $^\circ\text{C}$, $Pr = 3.02$, $\rho = 985$ kg/m 3 , $\mu_m = 4.71 \times 10^{-4}$ kg/m.s (at mean T),
 $\mu_w = 2.82 \times 10^{-4}$ kg/m.s (at wall T)
(i) Dittus-Boelter equation is $Nu = 0.023 Re^{0.8} Pr^n$, $n = 0.4$ for heating and 0.3 for cooling.
(ii) Sieder-Tate equation is, $Nu = 0.027 Re^{0.8} Pr^{1/3} \left(\frac{\mu_m}{\mu_w} \right)^{0.14}$. (08 Marks)
- 6 a. How are heat exchangers classified? (06 Marks)
b. What is fouling? List the factors that cause fouling. (04 Marks)
c. A counter flow heat exchanger of heat transfer area $A = 12.5$ m 2 is to cool oil [$C_{ph} = 2000$ J/kg.S] with water [$C_{pc} = 4170$ J/kg.S]. The oil enters at $T_{hi} = 100^\circ\text{C}$ and $m_h = 2$ kg/s, while the water enters at $T_{ci} = 20^\circ\text{C}$ and $m_c = 0.48$ kg/s. The overall heat transfer coefficient is $U_m = 400$ W/m ^2C . Calculate the exit temperature of water and the total heat transfer rate Q . (10 Marks)
- 7 a. Explain types of condensation. (04 Marks)
b. Sketch and explain regimes of pool boiling. (06 Marks)
c. A vertical square plate 30 by 30 cm, is exposed to steam at atmospheric pressure. The plate temperature is 98°C . Calculate the heat transfer and the mass of steam condensed per hour. What is the nature of flow?
Use the properties given below at 99°C
 $\rho_f = 960$ kg/m 3 , $\mu_f = 2.82 \times 10^{-4}$ kg/m.s, $K_f = 0.68$ W/m $^\circ\text{C}$, $T_{sat} = 100^\circ\text{C}$, $h_{fg} = 2255$ KJ/kg. (10 Marks)
- 8 a. Define the following with mathematical expressions:
(i) Spectral hemispherical emissivity. (ii) Hemispherical emissivity.
(iii) Spectral Black body emissive power. (iv) Blackbody emissive power. (08 Marks)
b. Explain concept of view factor and its physical significance. (04 Marks)
c. The emission of radiation from a surface can be approximated as a black body radiation at $T = 1000$ K.
(i) What fraction of the total energy emitted is below $\lambda = 5$ μm ?
(ii) What is the wave length below which the emission is 10.5 % of the total emission at 1000 K?
(iii) What is the wavelength at which the maximum spectral emission occurs at $T = 1000$ K? (08 Marks)

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